CNTT-E-111

BASIC ELECTRICITY AND ELECTRONICS

STUDENT HANDOUT NO. 204

SUMMARIES PROGRESS CHECKS FOR MODULES

21 LESSONS 5,5-1,5-2

JUNE 1984

SUMMARY
LESSON V

Basic Transistor Amplifier Circuit Analysis

In this lesson you will learn the two limits (cutoff and saturation) of a transistor, and the operating bias at which a transistor circuit may be designed to function (class A or class B). You will also cover three new circuits: push-pull amplifiers, phase-splitters and complementary-symmetry push-pull amplifiers.

Cutoff

Transistors are sometimes biased so they will not conduct (reverse biased).

When a transistor is reverse biased, the transistor is said to be cutoff. Since the base voltage will prevent current flow at cutoff, the transistor appears open between emitter and Vcc. For this reason you will measure source voltage (Vcc) across a cutoff transistor (See Figure 1).

Saturation

Saturation is the limit you reach when you increase forward bias until the transistor's conduction no longer increases. The transistor is then conducting as hard as it can (see Figure 1).

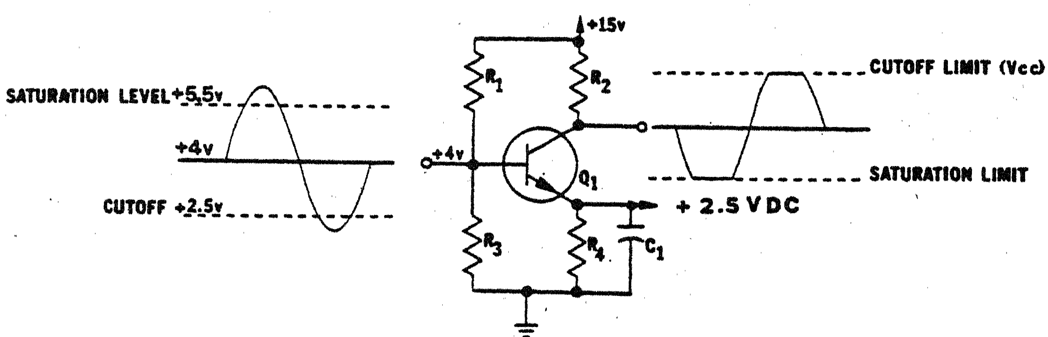


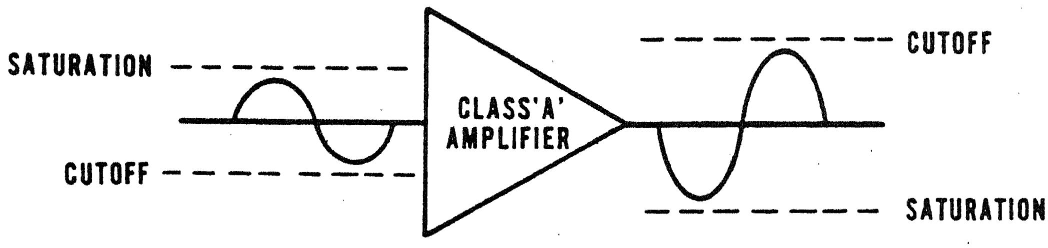
Figure 1

A saturated transistor acts almost like a short circuit. Nearly all of the Vcc will appear across the load resistor (R2).

Relative to cutoff and saturation, there are four (4) classes of bias, but we will discuss only two of the classes in this lesson.

Class A

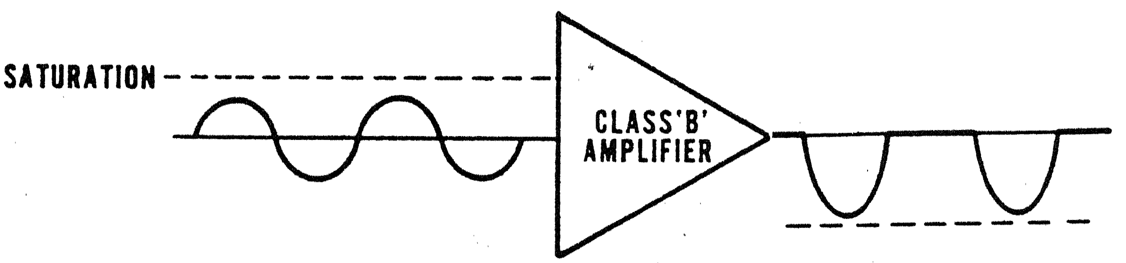
All the circuits you have studied have been Class A biased. The signal at the collector looks like the input signal, but it is larger and sometimes of opposite phase (Figure 2). In class A bias, the transistor conducts midway between cutoff and saturation with no signal input.



CLASS A AMPLIFIER
Figure 2

Class B

Class B bias sets the base bias at or just below the cutoff voltage of the transistor. This prevents the amplifier's conduction until the proper input signal is applied (see Figure 3).

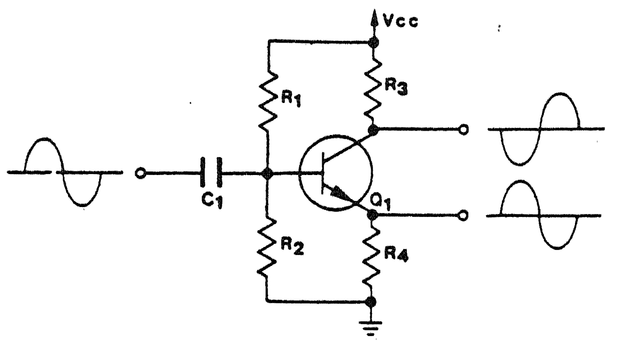


CLASS B BIAS
Figure 3

Depending on whether we use NPN or PNP transistors, the circuit will amplify the positive or negative portions of the input signal.

Phase-Splitter

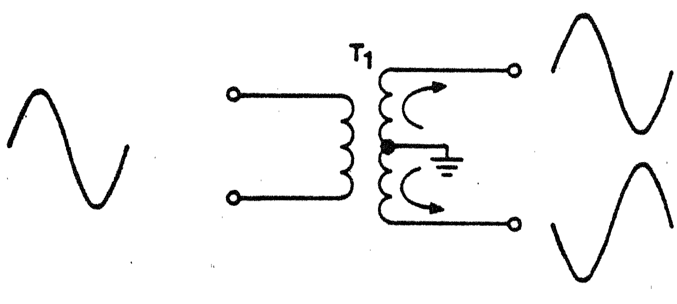
Some circuits we use require two input signals 180° out of phase but the same in amplitude. For this purpose we use a phase-splitter. See Figure 4.



PHASE-SPLITTER
Figure 4

The transistor in a phase-splitter circuit will be forward (class A) biased. The collector resistor and the emitter resistor will be of equal value so their voltage drops will be equal. Since the transistor circuit causes phase reversal of the input signal at the collector, the two output signals (collector and emitter) will be 180° out of phase.

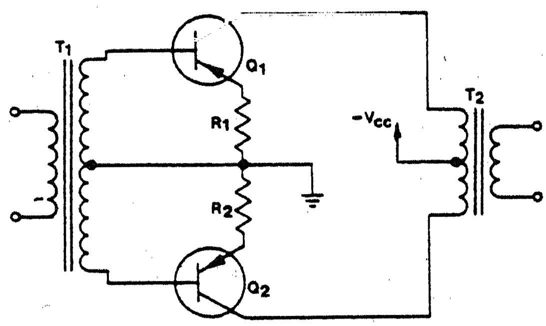
A center-tapped transformer will also provide a phase-splitter output (see Figure 5). The center tap effectively allows the secondary to act like two separate windings that provide two output signals equal in amplitude and 180° out of phase.



TRANSFORMER USED AS PHASE-SPLITTER
Figure 5

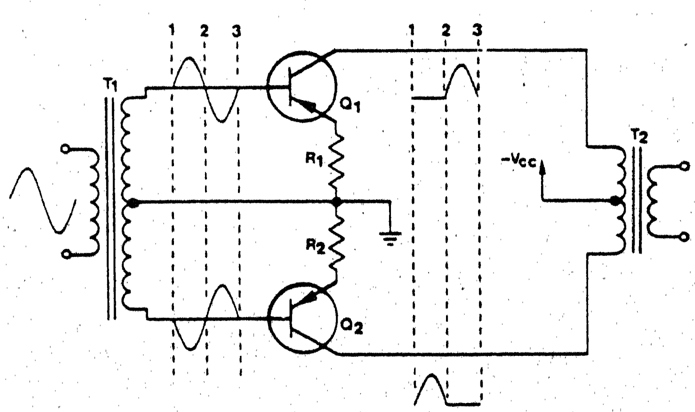
Push-pull Amplifier

A circuit that commonly uses a phase-splitter as an input is the push-pull amplifier (see Figure 6).



PUSH-PULL AMPLIFIER
Figure 6

Push-pull amplifiers provide high power amplification with minimum distortion. Basically a push-pull amplifier is two (2) common emitter circuits back to back. Most push-pull amplifiers are biased class B for efficient operation. The first circuit is formed by the top portion of T1, Q1, R1, and the top portion of T2. The other half is the bottom half of T1, Q2, R2, and the bottom half of T2. Each half of the output transformer (T2) acts as a collector load and output coupling device. The two signals out of our phase-splitter will cause one transistor to conduct and the other transistor to be in cutoff (see Figure 7). As the polarity of the signals changes, the transistor that was cut off will start to conduct and the other transistor will go into cutoff. Therefore, with class B bias on a push-pull amplifier you will have only one transistor conducting at a time.



PUSH-PULL AMPLIFIER WITH CURRENT WAVEFORMS
Figure 7

The amplified output signal from each transistor will be applied across its half of the transformer (T2). T2 will combine the two outputs of Q1 and Q2 and provide one output from its secondary, as shown in Figure 8.

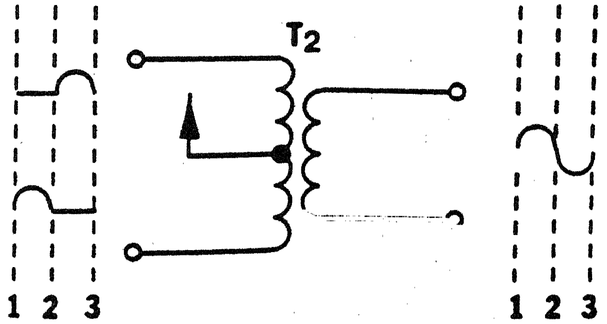
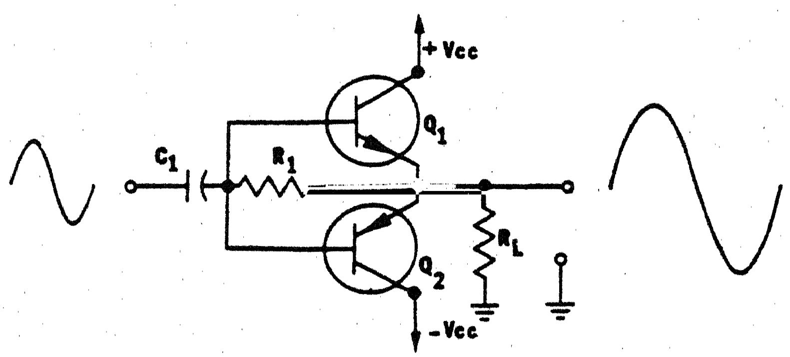


Figure 8

Now that we have studied common push-pull amplifiers and phase-splitters let's take a look at a push-pull amplifier that doesn't require a phase splitter. This type of push-pull amplifier is called a complementary-symmetry push-pull amplifier. A complementary-symmetry push-pull amplifier is simply a push-pull amplifier that uses an NPN transistor and a PNP transistor in conjunction, so we will need a power supply that provides both positive and negative voltages to properly bias a complementary-symmetry push-pull amplifier (see Figure 9).



COMPLEMENTARY-SYMMETRY PUSH-PULL AMPLIFIER
Figure 9

Just as common push-pull amplifiers can be biased class A or class B, so can the complementary symmetry push-pull amplifier. We normally use class B bias for more efficient operation of the circuit.

When we apply a positive signal to a class B biased complementary-symmetry push-pull amplifier, the NPN transistor (Q1) will conduct and the PNP transistor (Q2) will be cut off. The reverse is true when the input signal swings negative, Q2 will conduct and Q1 will be cut off.

The positive input signal will drive the NPN transistor and give a positive output signal across R_L; a negative input signal will drive the PNP transistor and provide a negative input signal across R_L. Because we use the common-collector configuration, we will not have phase inversion, and combining the output signals at R_L eliminates the need for an output transformer.

AT THIS POINT, YOU MAY PROCEED TO THE JOB PROGRAM, IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THIS LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH YOUR LEARNING CENTER INSTRUCTOR, UNTIL YOU UNDERSTAND THE MATERIAL IN THIS LESSON.

AUDIO-VISUAL RESPONSE SECTION

LESSON V

Basic Amplifier Operational Characteristics

1. A B C Circle One

FOR QUESTIONS 2-5 CIRCLE ONE CHOICE AND DRAW THE CORRECT OUTPUT SIGNAL

2. A B C D E F ______________________
3. A B C D E F ______________________
4. A B C D E F ______________________
5. A B C D E F ______________________

JOB PROGRAM FOR LESSON V PART I

Transistor Amplifier Analysis

EQUIPMENT AND MATERIALS

1. Device 6F16
   Templates "A" and "B"
2. Oscilloscope
3. Signal Generator
4. 1X Probe (3)
5. BNC-BNC Cable
6. BNC Tee Connector
7. Grounding Straps (2)

PROCEDURE

Turn on the signal generator and oscilloscope so they can warm up.

Open 6F16 training device carefully, ensuring the name plate is on top so the components will not fall out. Separate the top of the 6F16 from the component compartment.

Place template A on the top portion aligning the holes. Place the following components in the space designated.

Component	Space Marking
2N217 Transistor	2N217
1 Kohm Resistor	RL
1 Kohm Resistor	"D"
10 Kohm Resistor	"B"
18 Kohm Resistor	"A"
10 Kohm Potentiometer	"Pot"
10 μfd Capacitor	C1
1 Inch Shorting Strip	C
1 Inch Shorting Strip	F
1 Inch Shorting Strip	G
1 Inch Shorting Strip	R2

NOTE: TO REMOVE COMPONENTS USE THE PRY-UP TOOL PROVIDED WITH THE 6F16 DEVICE.

Adjust the potentiometer fully clockwise.

Obtain a line trace on the oscilloscope according to standard procedures. Use Channel 1 only.

Set up the signal generator according to standard procedures for a 1000 Hz (5% MODULATION LEVEL or 20 db ATTENUATION) audio signal.

Connect the BNC Tee Connector to the TRIGGER SOURCE input on the oscilloscope. Connect a BNC-BNC cable from the signal generator output to one side of the BNC Tee Connector. Connect a 1X probe to the other side of the Tee Connector. This probe will be used to supply a signal to the training device. The audio signal will also trigger the sweep across the CRT so that it will be synchronized with the start of the signal on the training device. All this means is that you will have a true picture of your signal with respect to time.

Set the TRIGGER SOURCE switch to external and adjust the TRIGGER LEVEL for a line trace.

Connect a 1X probe to Channel 1 of the oscilloscope, set the VOLTS/DIV knob to 1 Volt/div, and TIME/DIV to 100 μsecs/div.

Connect the two probes together and adjust signal generator % of MODULATION or ATTENUATION for 1 volt pk-pk sine wave (as displayed on the oscilloscope). Disconnect the probes.

Set the VOLTS/DIV knob for 2 volts/div, Channel 1 AC/DC switch to DC, and align the trace with the top horizontal line on the face of the CRT.

Connect Channel 1's probe to the transistor side of the load resistor RL, and its ground wire to position "G".

Energize the 6F16.

1. Record voltage. ______________________ volts.

2. Is this an indication of cut off or saturation? ______________.

3. Record bias voltage reading on the base. ________ volts.

The transistor used is a PNP, but the negative voltage on the base isn't large enough to forward bias the transistor. Therefore, the transistor is held at cut off. With no current flowing through the transistor there will be no voltage drop across the collector resistor. Source voltage will be present on the collector of the transistor.

Turn the potentiometer fully counter-clockwise to its stop.

4. Measure the base bias voltage and record. ______________ .

5. Measure collector voltage and record. ________________ .

6. Is this an indication of cut off or saturation? _________ .

You have seen that a small voltage increase on the base caused the tr
to go into saturation. The small voltage on the collector is the vol
drop across the transistor.

Adjust the potentiometer midway between its two stops.

Connect the audio signal, from the signal generator, to the template'
AC input.

Set the Channel 1 volts/div knob for 2 volts/div and the AC/DC switch
AC. Center the line trace.

Connect Channel 1's probe to the transistor side of the load resistor
and the ground wire to the shorting strip in position "G".

Readjust the potentiometer for a good sine wave on the face of the CR
Previously you turned the potentiometer clockwise to cut off the trans
and counter-clockwise to saturate it. Now slowly turn the potentiome
clockwise and observe the waveform on the CRT. The negative peaks wil
flatten out. The more you turn the potentiometer the more the bias is
lowered so that the positive peaks of the input signal cut the transis
off.

Turn the potentiometer back (counter-clockwise) until the full sine wa
appears on the CRT. Continue turning the potentiometer counter-clockw
slowly.

7. In your own words explain what you see on the CRT and why?

Readjust the potentiometer for a full sine wave on Channel 1.

Circuits are designed for a specific class of operation. In lesson V
learned about two classes, A & B. A circuit designed for class A oper
will have a bias on the transistor that will allow all of the input
signal to be amplified.

Connect your third 1X probe to Channel 2 input on the oscilloscope. S
the DISPLAY MODE switch to its chop position, and position the second
trace below the amplified sine wave; decrease the Channel 2 VOLTS/DIV
.05 Volts/Div to allow both signals to be seen. Set the Channel 2 AC/
switch to DC. Attach a 1X probe to the base side of the 10 Kohm resis
in position "B". Adjust the VOLTS/DIV so Channel 2's sine wave will b
about the same height as Channel 1's. You have the input sine wave on
Channel 2, and the amplified output sine wave on Channel 1. Notice th
the two signals are out of phase with each other. Remember, common em
amplifiers give phase inversion. The amplifier circuit is now set up
class A operation. The full input sine wave is being amplified.

Turn the potentiometer back and forth a couple of times, and observe the display as it increases and decreases. The displayed signal increases and decreases because the oscilloscope is monitoring the DC level (bias) on the base of the transistor as well as the AC signal. Turning the potentiometer clockwise increased the DC level and the input signal amplitude drove the transistor into cut off during the positive portion. Turning the potentiometer counter-clockwise decreased the DC level and the input signal drove the transistor into saturation during the negative portion.

8. Class A amplifiers allow (all/part/none) of the input signal to be amplified.

For class B operation of this same circuit all that is needed is to adjust the base bias with the potentiometer so only half of the input sine wave will be amplified. Adjust the potentiometer to display only the negative half of the output signal. De-energize the 6F16.

9. Class B operation allows 90°/180°/270°/360° of the input signal to be amplified.

In the next part of the job program we will look at the complementary-symmetry circuit. Remove the components from the Common Emitter Amplifier circuit and place them in their proper places in the component half of the 6F16. Exchange template A for Template B - Forward Biased Complementary-Symmetry Amplifier. Build the circuit by placing components in the spaces marked. Place a 100 Kohm resistor in the position marked R_{IN}. Set shorting strips in positions A, B, C, and G. All positions should be filled. Energize the 6F16.

Connect the Channel 1 probe to the emitter side of RL with its ground wire to position "G".

Adjust the signal generator for 1v peak-to-peak and connect the generator probe to the input side of RIN.

Connect the Channel 2 oscilloscope probe to the input side of capacitor C1.

The sine waves should be in phase. There is no phase inversion with a common collector circuit, and a complementary-symmetry amplifier uses two common collector circuits. The first is Q1, with its collector tied to -4v, the emitter lead to ground through load resistor RL, and the input signal applied to the base. The second common collector is Q2, with its collector connected back through position "C" to +4 volts, emitter lead to ground through load resistor RL, and the input signal applied to its base. The output of both circuits is developed across load resistor RL. Each circuit works only part of the time. Q1 is a PNP transistor; therefore, the negative half of the input signal will cause it to conduct, where Q2 is a NPN type and only the positive portion causes it to conduct. The complete sine wave developed across RL is displayed on Channel 1.

Secure the power to the transistor circuit when removing or replacing transistors. Sudden surges of current through the transistor could destroy it if you don't. Remove Q1.

10. Which portion of the sine wave is missing? ________________.

Replace Q1.

Remove Q2.

11. Which portion of the sine wave is missing? ________________.

Each transistor conducts half of the time.

12. What class operation is their bias? ______________________.

If you have noticed, the output signal looks the same amplitude as the input signal. Remember, with the oscilloscope you are looking at voltage. The complementary-symmetry amplifier is used in place of a push-pull amplifier to give us greater power. Speakers or headsets can be attached directly to emitters saving the cost of transformers required for a push-pull amplifier.

13. De-energize the 6F16 device. Using the pry-up tool, remove components and replace them in their proper place in the component half of the 6F16 device. Return all equipment to its proper stowage.

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JOB PROGRAM
FOR
LESSON V

PART 2

Transistor Amplifier Analysis

REFERENCE(S)

1. Technical Manual for NIDA 202 Amplifier

EQUIPMENT AND MATERIALS

1. Oscilloscope
2. Signal Generator
3. NIDA 202 Amplifier
4. 1X Probe (3)
5. BNC - BNC Cable
6. BNC "TEE" Connector

PROCEDURE

1. Set up the oscilloscope for dual trace operation. Connect the signal generator audio output to the TRIGGER SOURCE of the oscilloscope using the BNC cable and BNC "TEE" connector. Connect the three 1X probes to the CHANNEL 1 INPUT, CHANNEL 2 INPUT and the "TEE" connector.

2. Set up the NIDA 202 Amplifier as follows:

   a. Remove the top cover and insure that there is no printed circuit card installed.

   b. Remove the bottom cover.
   c. Turn the SPEAKER SWITCH to "off".
   d. Turn the amplifier over so the bottom is accessible.

3. The schematic for the NIDA 202 chassis and the printed circuit board PC 202 may be found in the NIDA 202 Technical Manual. Using the schematic as a reference, locate the power supply input circuit components. With the NIDA 202 Amplifier plugged in, there is 115 Volts AC on these components, so remember where these components are, and stay away from them. The voltage is dangerous. Locate CR6 and C2 on the schematic. These components and all the components to the left of CR6 and C2 are associated with the power supply. Locate the power supply area of the PC board. You will not be required to work on the power supply now, so, keep clear of these components.

Refer to the schematic drawing and complete the following statements.

4. Q2 and its associated circuitry comprise a/an

   a. common base amplifier
   b. phase-splitter
   c. common emitter amplifier.
   d. emitter follower amplifier.

5. Transformer T2 is used as a/an

   a. power transformer.
   b. phase-splitter.
   c. output transformer.

6. Q3, Q4, and their associated circuitry comprise a

   a. complementary-symmetry amplifier.
   b. cascaded amplifier.
   c. phase-splitter.
   d. push-pull amplifier.

7. The push-pull amplifier in the NIDA 202 is biased slightly above cutoff with no signal applied. This is done because transistors often have non-linear gain at low signal voltages. Steps 9c and 10a in this job program show the wave forms for the circuit biased slightly above cutoff (+0.6V) by the voltage drop across CR7 (step 9c) and the circuit biased at cutoff (Step 10a).

8. Connect the 1:1 probe from the "TEE" Connector to the ext. trigger input on the oscilloscope to J4, PIN 1 (White/Blue Wire). (This is the input signal to the push-pull amp.) Set the signal generator for a 1 KHz audio out at 20V p-p.

   NOTE: Turn the volume control on the front panel fully clockwise (CW), then 1/4 turn counter-clockwise (CCW).

9. Energize the NIDA 202, measure waveforms, and answer the following questions:

   a. What is the gain of Q2? Connect the Channel "1" probe to the left side of R5 and the Channel "2" probe to the right side of R5.

   ______________________________.

   b. What is the p-p voltage and phase relationship between the collector signals of Q3 and Q4 _______________ V p-p __________phase.

   NOTE: The metal case of the transistor is the same as the collector.

   c. What is the p-p output voltage of the push-pull amplifier?

   ____________________________V p-p.

10a. De-energize and unplug the NIDA 202. Use a jumper to short out CR7. Move the input probe (from the signal generator) to the right side of C3 and set the signal generator output for 1Vp-p. (Measure on the oscilloscope). Re-energize the NIDA 202 and check the output. Do you now have a "clean" sine wave? ____________________.

10b. What is happening to the conduction times of Q3 and Q4?

a. When Q3 conducts, Q4 conducts.
b. When Q3 cuts off, Q4 conducts.
c. When Q3 cuts off, Q4 does not start conducting immediately.
d. When Q3 conducts, Q4 does not cut off at the same time.

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PROGRESS CHECK
LESSON V

Basic Transistor Amplifier Circuit Analysis

1. When a transistor is at cutoff the

   a. transistor acts as a short circuit.
   b. output load acts as an open circuit.
   c. transistor acts as an open circuit.
   d. output load acts as a short circuit.

2. If the voltage across a transistor is about equal to Vcc, the transistor is ________________.

3. If the voltage across its collector resistor is about equal to Vcc, a transistor is ________________.

4. Class A bias is defined as current flow through the transistor for _______ of the input signal.

   a. 90°
   b. 270°
   c. 360°
   d. 180°

5. Class B bias is defined as current flow through the transistor for _______ of the input signal.

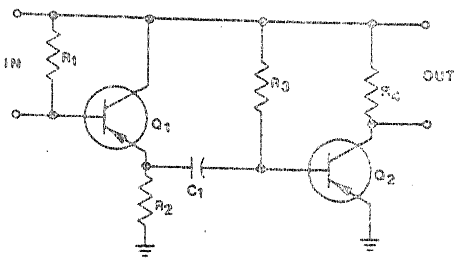
   a. 180°
   b. 360°
   c. 270°
   d. 90°

6. A push-pull amplifier provides

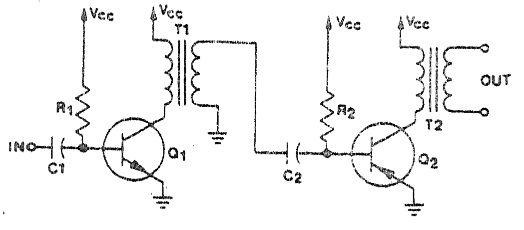
   a. high voltage gain.
   b. high output power.
   c. large DC voltage.
   d. current regulation.

7. Which of the schematics illustrated below represents a push-pull amplifier?

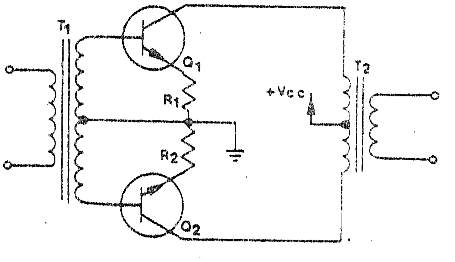
a.



b.



c.



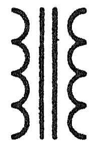
8. The function of a phase-splitter circuit is to

a. provide two equal signals 180° out of phase.
b. provide two equal, in-phase signals.
c. increase the frequency of the input signal.
d. increase the frequency of the output signal.

9. Which of the devices illustrated below could function as a phase-splitter?

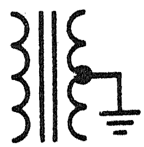
a.

c.



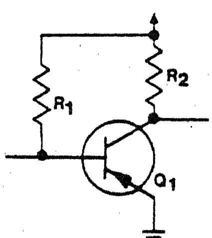
b.

d.

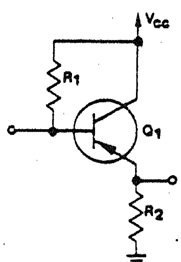


10. Which of the circuits illustrated below could function as a phase-splitter?

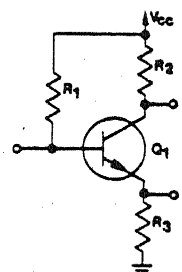
a.



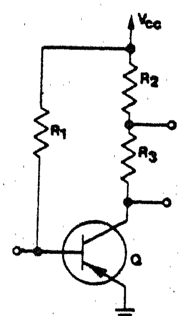
b.



c.



d.

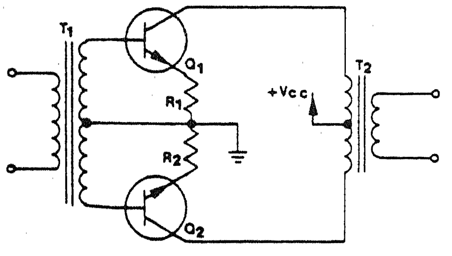


11. A complementary-symmetry push-pull amplifier is a push-pull amplifier that uses

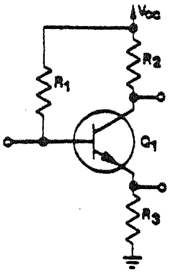
a. two PNP transistors.
b. an NPN or a PNP transistor.
c. an NPN and a PNP transistor.
d. two NPN transistors.

12. Which of the circuits illustrated below represents a complementary symmetry push-pull amplifier?

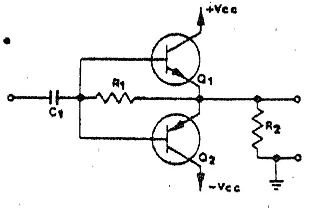
a.



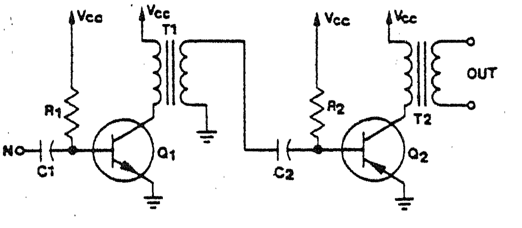
b.



c.



d.



CHECK YOUR ANSWERS TO THIS PROGRESS CHECK WITH THE ANSWERS IN THE BACK OF YOUR STUDENT GUIDE. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ANY PART OF THIS LESSON YOU SHOULD CONSULT YOUR LEARNING CENTER INSTRUCTOR FOR ASSISTANCE AND REMEDIATION. IF YOU ANSWERED ALL QUESTIONS IN THE PROGRESS CHECK CORRECTLY, CONSULT YOUR LCI FOR ASSIGNMENT TO THE MODULE TEST.

ANSWER SHEET
FOR
JOB PROGRAM
LESSON V
PART I

Transistor Amplifier Analysis

1. -8.2 volts

2. cut off

3. 0 - -.15 volts

4. -.16 volts

5. -.1 volts

6. saturation

7. Positive portion flattened out, the potentiometer raised the bias to where the input signal drove the transistor into saturation (or words to that effect).

8. all

9. 180°

10. Negative

11. Positive

12. "B"

Due to a difference in transistor characteristics, aging of components, and power supply operation your answers may not be exactly the same as those given above. The voltage relationships still clearly indicate circuit conditions.

ANSWER SHEET
FOR
JOB PROGRAM
LESSON V
PART 2

Transistor Amplifier Analysis

4. (c) common emitter emplifier

5. (b) phase emitter

6. (d) push-pull amplifier

9a. 56 ± 10%

9b. 10 V(p-p), 180° out of phase

9c. 2.2 V(p-p) ± 10%

10a. No

10b. (c) When Q3 cuts off, Q4 does not start conducting immediately.

ANSWER SHEET
FOR
PROGRESS CHECKS
LESSON V

Basic Transistor Amplifier Circuit Analysis

QUESTION NO.	CORRECT ANSWER
1	c
2	Cut off
3	Saturated
4	c
5	a
6	b
7	c
8	a
9	d
10	c
11	c
12	c

N O T E S

NOTES - NOTES